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ABSTRACT

This paper briefly reviews how subjects enhance performance by favoring some stimuli over others. The author calls the mechanism by which this is achieved "expectancy", a generic term including preparatory set, behavioral hypotheses, orienting reflex, and anticipatory goal responses. Temporal and event expectancy are contrasted. Verbal prediction before presentation of the stimulus is a method commonly used to understand expectancy state. Theoretical concensus in regard to interpreting the verbal prediction effect are presented. Also discussed is whether the subject anticipates seeing a particular stimulus or executing a particular response. The primary assumption emphasized is that expectancy is a memory phenomenon. (KS)

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MPA, May, 1976

Expectancy in Rapid Decision-Making

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In compliance with the request of the program committee, I shall attempt to briefly review our approach to the problem of expectancy in rapid decision-making. Instead of presenting new data, I wish to emphasize basic issues, conclusions, interesting questions, and continuing problems.

By way of introduction, it may be noted that every theorist attempting to deal with basic cognitive processes has felt the need to incorporate some mechanism to operate selectively upon input stimulation. It has been the explanation of last resort. The ability of subjects to enhance performance by favoring some stimuli over others has been demonstrated in a variety of experimental settings. Many theoretical labels have been applied to this performance enhancement, including preparatory set, behavioral hypotheses, orienting reflex, and anticipatory goal responses. I subsume all of these under the generic label of expectancy. An interesting theoretical question is whether a single expectancy concept is sufficient to account for all experimental results.

In discussing the role of expectancy in choice reaction time experiments, one very basic distinction must be introduced immediately. Two types of expectancy notions are used in the choice reaction time literature--temporal expectancy and event expectancy. Temporal expectancy refers to knowledge of <u>when</u> an event will occur in the temporal stream. I shall not be greatly concerned with the role of temporal expectancy and will concentrate instead on event expectancy. Event expectancy refers to knowledge of <u>which</u> of two or

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more stimuli will be presented. An interesting and as yet largely unexplored question is the relationship between temporal and event expectancy in information processing.

Several methods have been used to study event expectancy. The most familiar is to manipulate stimulus or response probability. The subject's ability to probability match his responses to the probability of a stimulus is a primitive demonstration of the role of expectancy in decision-making. A more refined technique is to present a cue partially correlated with the to-be-presented stimulus. Subjects will use predictive information--even very subtle cues--to improve their performance. A third method--and the one preferred in our research--requires subjects to predict which of the possible stimuli they expect to see or hear on the next trial. This verbal prediction paradigm requires subjects to make a verbal prediction of either the stimulus to be presented or of the response to be executed before the stimulus is actually presented. Therefore, the subject's professed expectancy state is observed directly.

Knowledge of the subject's predictions and the actual stimulus presented allows the experimenter to categorize each reaction time as based on either a correct prediction or an incorrect prediction. Conditionalizing on correctness of predictions has a powerful effect on reaction time as demonstrated in the first slide. The verbal prediction effect occurs in virtually every subject

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Present Slide 1

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and differences between correct and incorrect predictions range in magnitude up to more than 200 msec. If one argues that on every trial, the subject is prepared for at least one stimulus, then the observed reaction times are a

mixture of correct and incorrect anticipations. If one further argues that when the probability of a stimulus varies, subjects will attempt to match their predictions to the probability of occurrence, the probability effect in choice reaction time can be attributed to a weighted average of correctly and incorrectly anticipated stimuli. In Figure 1, where the more frequent stimulus occurs twice as often as the less frequent stimulus, and is also predicted twice as often, an unweighted average of the points at each frequency level would yield little or no frequency effect, while the weighted average of the predictions shows the typical increase in reaction time with a decrease in frequency, as does the control curve with no predictions. A later experiment, published with John Craft, demonstrated that the weighted average of correctly and incorrectly anticipated stimuli makes a large contribution to the variance of the frequency effect in choice reaction time, although there is a residual frequency effect as well when the probability of correct anticipations is removed. This mixture interpretation has difficulties when one attempts to move beyond predictions of means to distributional characteristics of reaction times. Nevertheless, as a first approximation, the mixture interpretation demonstrates the large contribution of subjective anticipations in choice reaction time and to the probability effect in CRT.

To turn to another question that occupied a great deal of our attention in the early research and continues to be of interest: Does the subject anticipate seeing a particular <u>stimulus</u> or does he anticipate executing a particular <u>response</u>? The relative contribution of stimulus and response factors in choice reaction time has been a long standing problem in choice reaction time. Our attack on the question of stimulus or response anticipation in the verbal prediction situation used a three-stimulus, two-response paradigm

in which two of the stimuli were paired with one response and the third stimuli with a second response. As shown on the next slide, one can use

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Present Slide 2

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stimulus and response interpretations to generate very strong predictions about the pattern of outcomes. Fully expecting to find that both stimulus and response factors would make a contribution, we were surprised that only stimulus factors played a role, as demonstrated in the next slide. In this

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Present Slide 3

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data, the probability of each stimulus is held equal. Later experiments manipulated the relative frequency of the various stimuli, distorting the shape of the three functions but without altering the conclusion that stimulus factors predominate in the verbal prediction effect.

A recent study with Mike Suelzer extended the verbal prediction results to a situation in which subjects were requested to predict which response they would make when one of the stimuli was paired with a free-choice response, that is, either response could be made to that particular stimulus. Generally, the pattern of results was very consistent with a stimulus anticipation interpretation of the prediction effect. One of the most compelling aspects of the data was a condition in which a free-choice stimulus was presented after a prediction of one of the two response alternatives. Not surprisingly, subjects tended to follow their response prediction in executing the response to the free-choice stimulus, that is, if they predicted Response 1 when the free-choice stimulus occurred, they were more likely to make Response 1

than Response 2. However, their latencies did not differ as a function of which response was executed. In other words, the response prediction affected the choice of responses but did not affect the latency. Latencies were reduced only in the case where the subjects could correctly anticipate which stimulus was to occur. That is, response predictions facilitated performance only when it could be uniquely identified with a particular stimulus.

To turn to theoretical concerns, how are we to interpret the verbal prediction effect? As working hypotheses, we have considered three classes of models: a switch-setting interpretation, a memory-scan interpretation, and a recency or trace activation interpretation. The switch-setting view is the simplest--it only presumes that some stage in information processing is facilitated by advance information, like throwing a switch before the stimulus is displayed. The switch-setting interpretation is consistent with mixture models but has the same limitations. Thus far, the trace activation or recency interpretations have had the least amount of theoretical effort. Borrowing from Posner's notions of trace activation, one could argue that the verbal prediction activates a memory trace for the to-be-presented stimulus. The state of activation or preparation decreases with time, suggesting interesting interrelationships between temporal and event expectancies. Most of our theoretical effort has concentrated on memory scanning models like those proposed by Steinberg, Theois, and others.

In our view of a memory scanning model, applied to the verbal prediction situation, the subject is hypothesized to have a working memory at least as large as the number of stimulus alternatives in the task. On any trial, the stimulus alternatives are arranged in memory in a particular order. The most expected stimulus is at the top of the memory stack, and the least expected at the bottom. A prediction is generated by examining the top

item or items in the stack, and a reaction time response is made by comparing the presented stimulus with items in the stack in the order of their arrangement. Between trials, the stack may be rearranged. Mike Hacker and I tested these notions by extending verbal predictions to a situation in which the subjects were required to make two predictions from four possible alternatives. The four stimuli were mapped onto two responses in a pair-wise fashion. Before each presentation, the subjects were required to make two predictions, a most-likely and a second-most-likely stimulus. Two questions were of central empirical concern. First, would there be a reaction time enhancement for the second of two predictions? Second, what is the decision latency as a function of the hypothetical memory position as determined by the subject's verbal predictions? The results are shown in the next slide, where reaction

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Present Slide 4

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time is a linearly increasing function of expected memory stack position. The data are consistent with a self-terminating memory scanning interpretation, where memory Positions 1 and 2 are associated with the first- and second-most-likely predictions and Position 3.5 refers to the means of the third and fourth unpredicted position. The linear relationship occurs for individual subjects as well as the group data, as shown in the next two slides.

Present Slides 5 and 6

Allow me to finish this brief resume by raising a few questions for future research. I am convinced that the interpretation of expectancy has

important consequences, not only for our understanding of rapid decision making, but also for other basic cognitive processes, such as perception, social attribution, and learning. Consequently, one important avenue for further research is in determining the contribution of expectancy to other choice reaction time and decision-making processes, such as the speed-accuracy trade-off, memory retrieval, information integration, and pattern learning. Most importantly, we need to learn more about the expectancy mechanism *per se* by developing and testing models. One feature of memory search models deserving further study is the dynamic arrangement of the memory stack. Does the order of items in memory change within a trial? Rearrangement would be equivalent to a subject "changing his mind" as he attempts to anticipate a stimulus. We are now gathering evidence that suggests that subjects do indeed change their minds by rearranging the order of items in memory. But that's another story for another time.

Let me conclude by emphasizing our primary assumption in our research on expectancy, which is that expectancy is a memory phenomenon. Subjects use past information to order the processing of anticipated stimuli and to facilitate performance when anticipation is correct at the cost of slower or less efficient processing when anticipation is incorrect.